

第四章

4.1 (1) 由于三台单相变压器结构、参数相同，当初级接三相对称电压，次级空载时，初级绕组中流过对称三相空载电流，产生三相对称磁通，这时初、次级绕组中的感应电动势三相对称，相应的初、次级绕组的相电压和线电压均对称。

(2) 当次级接三相对称负载时，次级绕组中流过对称三相电流；初级流过的电流也是三相对称的，因仅有对称电流和对称的三相磁通，所以绕组中的压降和感应电动势也是三相对称的，对应的初、次级的相电压和线电压也均对称。

(3) 当次级 a 相接电阻性负载 $r_{L^*} = 1$ ，b、c 空载时，变压器单相运行，设 $\dot{U}_{A1^*} = 1 + j0$ ，各量正方向按变压器惯例，得单相负载电流

$$-\dot{I}_* = \frac{3\dot{U}_{A1^*}}{3Z_{L^*} + 2Z_{K^*} + Z_{2^*} + Z_{m0^*}}$$

式中

$$Z_{K^*} = u_{K^*} = 0.05$$

$$r_{K^*} = u_{a^*} = 0.02$$

$$x_{K^*} = \sqrt{Z_{K^*}^2 - r_{K^*}^2} = \sqrt{0.05^2 - 0.02^2} = 0.0458$$

因为是三相变压器组，所以

$$Z_2 + Z_{m0} = Z_m$$

$$Z_{m^*} = \frac{U^*}{I_{0^*}} = \frac{1}{0.05} = 20$$

$$r_{m^*} = \frac{P_{0^*}}{I_{0^*}^2} = \frac{0.01}{0.05^2} = 4$$

$$x_{m^*} = \sqrt{Z_{m^*}^2 - r_{m^*}^2} = \sqrt{20^2 - 4^2} = 19.6$$

$$\begin{aligned} \text{负载电流} \quad -\dot{I}_* &= \frac{3 \times 1}{3 \times 1 + 2(0.02 + j0.0458) + 4 + j19.6} \\ &= 0.143 \angle -70.3^\circ \end{aligned}$$

各项电流为

$$\text{次级} \quad \dot{I}_{a^*} = \dot{I}_* = 0.143 \angle 109.7^\circ$$

$$\dot{I}_{b^*} = \dot{I}_{c^*} = 0$$

$$\text{初级} \quad \dot{I}_{A^*} = -\frac{2}{3}\dot{I}_* = 0.095 \angle -70.3^\circ$$

$$\dot{I}_{B^*} = \frac{1}{3} \dot{I}_* = 0.0477 \angle 109.7^\circ$$

$$\dot{I}_{C^*} = \frac{1}{3} \dot{I}_* = 0.0477 \angle 109.7^\circ$$

a 相电压 $-\dot{U}_{a^*} = \dot{U}_{A1^*} + \dot{I}_{a1^*} Z_{K^*} + \dot{I}_{a2^*} Z_{K^*} + \dot{I}_{a0^*} (Z_{2^*} + Z_{m0^*})$

或 $-\dot{U}_{a^*} = -\dot{I}_* Z_{L^*} = 0.143 \angle -70.3^\circ = \dot{U}_{A^*}$

b 相电压 $-\dot{U}_{b^*} = \dot{U}_{B1^*} + \dot{I}_{b1^*} Z_{K^*} + \dot{I}_{b2^*} Z_{K^*} + \dot{I}_{b0^*} (Z_{2^*} + Z_{m0^*})$

或 $-\dot{U}_{b^*} \approx \dot{U}_{B1^*} + \dot{I}_{b0^*} (Z_{2^*} + Z_{m0^*})$

$$= -\frac{1}{2} - j\frac{\sqrt{3}}{2} + \frac{1}{3} \times 0.143 \angle 109.7^\circ (4 + j19.6)$$

$$= -1.447 - j1.0 = 1.758 \angle -145.35^\circ = \dot{U}_{B^*}$$

c 相电压 $-\dot{U}_{c^*} = \dot{U}_{C1^*} + \dot{I}_{c1^*} Z_{K^*} + \dot{I}_{c2^*} Z_{K^*} + \dot{I}_{c0^*} (Z_{2^*} + Z_{m0^*})$

或 $\dot{U}_{c^*} \approx \dot{U}_{C1^*} + \dot{I}_{c0^*} (Z_{2^*} + Z_{m0^*})$

$$= -\frac{1}{2} + j\frac{\sqrt{3}}{2} + \frac{1}{3} \times 0.143 \angle 109.7^\circ (4 + j19.6)$$

$$= -1.447 + j0.731 = 1.62 \angle 153.2^\circ = \dot{U}_{C^*}$$

线电压 $\dot{U}_{AB^*} = \dot{U}_{ab^*} = \dot{U}_{A^*} - \dot{U}_{B^*} = 0.143 \angle -70.3^\circ - 1.76 \angle -145.3^\circ$

$$= 1.728 \angle 30.05^\circ$$

$$\dot{U}_{BC^*} = \dot{U}_{bc^*} = \dot{U}_{B^*} - \dot{U}_{C^*} = -1.447 - j1.0 + 1.447 - j0.731$$

$$= 1.731 \angle -90^\circ$$

$$\dot{U}_{CA^*} = \dot{U}_{ca^*} = \dot{U}_{C^*} - \dot{U}_{A^*} = -1.447 + j0.731 - 0.143 \angle -70.3^\circ$$

$$= 1.728 \angle 149.92^\circ$$

由上述结果可看出，由于带了单相负载造成负载相（a 相）电压降低，开路相（b、c 相）电压升高。由于电源电压对称，所以线电压仍是三相对称的。